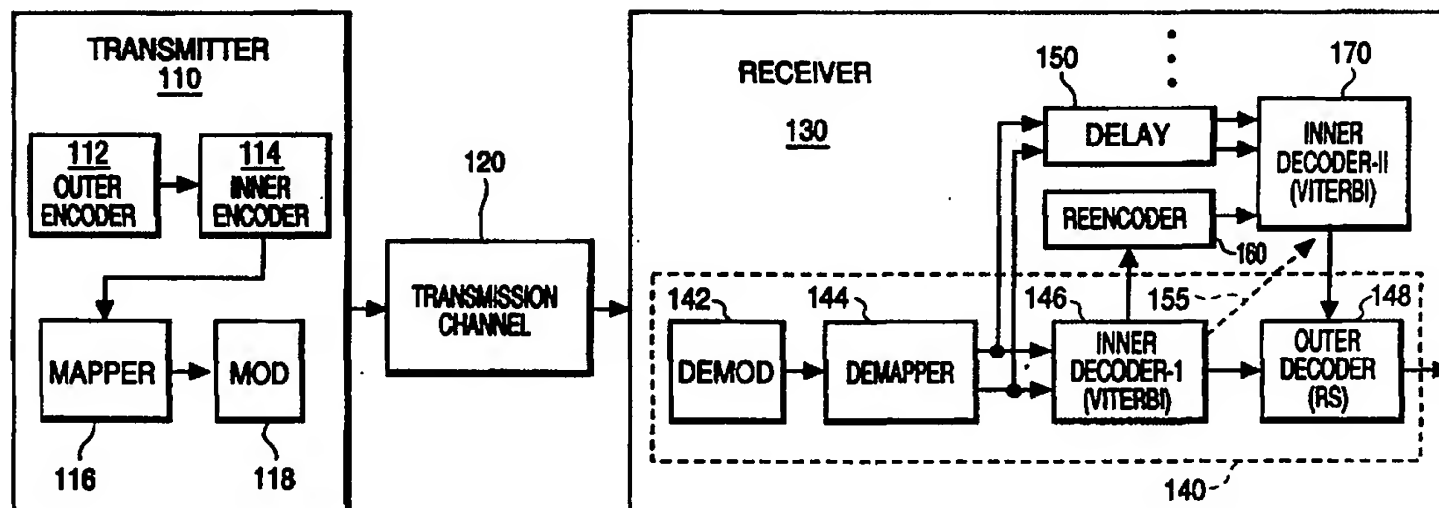




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>H04L 27/38, H04B 7/185</b>	<b>A1</b>	(11) International Publication Number: <b>WO 99/00957</b> (43) International Publication Date: 7 January 1999 (07.01.99)
<p>(21) International Application Number: PCT/US98/12641</p> <p>(22) International Filing Date: 17 June 1998 (17.06.98)</p> <p>(30) Priority Data: 08/884,947 30 June 1997 (30.06.97) US</p> <p>(71) Applicant: THOMSON CONSUMER ELECTRONICS, INC. [US/US]; 10330 North Meridian Street, Indianapolis, IN 46290-1024 (US).</p> <p>(72) Inventor: RAMASWAMY, Kumar; 9417 College Drive No. B, Indianapolis, IN 46240 (US).</p> <p>(74) Agents: TRIPOLI, Joseph, S. et al.; GE &amp; RCA Licensing Management Operation, Inc., P.O. Box 5312, Princeton, NJ 08543 (US).</p>		<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> <i>With international search report.</i></p>

(54) Title: APPARATUS AND METHOD FOR PROCESSING A QUADRATURE AMPLITUDE MODULATED (QAM) SIGNAL



(57) Abstract

Apparatus (130) and method for receiving a QAM signal using a backward compatible hierarchical coding scheme to increase data transmission using finer constellations, while maintaining compatibility with existing Direct Broadcasting Satellite (DBS) systems. The apparatus employs multiple stages of decoders (146,170) such that the finer constellations of the QAM signal are unraveled at different stages.

***FOR THE PURPOSES OF INFORMATION ONLY***

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

<b>AL</b>	Albania	<b>ES</b>	Spain	<b>LS</b>	Lesotho	<b>SI</b>	Slovenia
<b>AM</b>	Armenia	<b>FI</b>	Finland	<b>LT</b>	Lithuania	<b>SK</b>	Slovakia
<b>AT</b>	Austria	<b>FR</b>	France	<b>LU</b>	Luxembourg	<b>SN</b>	Senegal
<b>AU</b>	Australia	<b>GA</b>	Gabon	<b>LV</b>	Latvia	<b>SZ</b>	Swaziland
<b>AZ</b>	Azerbaijan	<b>GB</b>	United Kingdom	<b>MC</b>	Monaco	<b>TD</b>	Chad
<b>BA</b>	Bosnia and Herzegovina	<b>GE</b>	Georgia	<b>MD</b>	Republic of Moldova	<b>TG</b>	Togo
<b>BB</b>	Barbados	<b>GH</b>	Ghana	<b>MG</b>	Madagascar	<b>TJ</b>	Tajikistan
<b>BE</b>	Belgium	<b>GN</b>	Guinea	<b>MK</b>	The former Yugoslav Republic of Macedonia	<b>TM</b>	Turkmenistan
<b>BF</b>	Burkina Faso	<b>GR</b>	Greece	<b>ML</b>	Mali	<b>TR</b>	Turkey
<b>BG</b>	Bulgaria	<b>HU</b>	Hungary	<b>MN</b>	Mongolia	<b>TT</b>	Trinidad and Tobago
<b>BJ</b>	Benin	<b>IE</b>	Ireland	<b>MR</b>	Mauritania	<b>UA</b>	Ukraine
<b>BR</b>	Brazil	<b>IL</b>	Israel	<b>MW</b>	Malawi	<b>UG</b>	Uganda
<b>BY</b>	Belarus	<b>IS</b>	Iceland	<b>MX</b>	Mexico	<b>US</b>	United States of America
<b>CA</b>	Canada	<b>IT</b>	Italy	<b>NE</b>	Niger	<b>UZ</b>	Uzbekistan
<b>CF</b>	Central African Republic	<b>JP</b>	Japan	<b>NL</b>	Netherlands	<b>VN</b>	Viet Nam
<b>CG</b>	Congo	<b>KE</b>	Kenya	<b>NO</b>	Norway	<b>YU</b>	Yugoslavia
<b>CH</b>	Switzerland	<b>KG</b>	Kyrgyzstan	<b>NZ</b>	New Zealand	<b>ZW</b>	Zimbabwe
<b>CI</b>	Côte d'Ivoire	<b>KP</b>	Democratic People's Republic of Korea	<b>PL</b>	Poland		
<b>CM</b>	Cameroon	<b>KR</b>	Republic of Korea	<b>PT</b>	Portugal		
<b>CN</b>	China	<b>KZ</b>	Kazakstan	<b>RO</b>	Romania		
<b>CU</b>	Cuba	<b>LC</b>	Saint Lucia	<b>RU</b>	Russian Federation		
<b>CZ</b>	Czech Republic	<b>LI</b>	Liechtenstein	<b>SD</b>	Sudan		
<b>DE</b>	Germany	<b>LK</b>	Sri Lanka	<b>SE</b>	Sweden		
<b>DK</b>	Denmark	<b>LR</b>	Liberia	<b>SG</b>	Singapore		
<b>EE</b>	Estonia						

APPARATUS AND METHOD FOR PROCESSING A QUADRATURE  
AMPLITUDE MODULATED (QAM) SIGNAL

5           The present invention relates to a method and apparatus for decoding a Quadrature Amplitude Modulated (QAM) signal with a high order symbol constellation.

Power and bandwidth are resources that are carefully  
10 conserved by digital transmission systems through the proper selection of modulation and error correction schemes. Quadrature Amplitude Modulation (QAM) is one form of multilevel amplitude and phase modulation that is frequently employed in digital communication. A QAM system modulates a source signal into an  
15 output waveform with varying amplitude and phase.

QAM is a form of two-dimensional symbol modulation composed of a quadrature (orthogonal) combination of two PAM (pulse amplitude modulated) signals. Data to be transmitted is mapped to a  
20 two-dimensional, four quadrant signal space, or constellation, having a plurality of signal (phasor) points each representing a possible transmission level. Each constellation signal point is commonly called a "symbol" and is defined by a unique binary code. The QAM constellation employs "I" and "Q" components to signify the in-phase and quadrature components, respectively, where a QAM data word or  
25 symbol is represented by both I and Q components.

QAM signals may employ words or symbols of different lengths and/or constellation shapes (e.g., circular, square, rectangular, cross,  
30 hexagonal or any arbitrary shapes). Although the present invention

2

is described using a square QAM constellation, those skilled in the art will realize that the present invention can be modified for other QAM constellation shapes or QAM signal word of different lengths.

5           Generally, an increase in the number of phasor points (finer, higher order constellations) within the QAM constellation permits a QAM signal to carry more information, but the increase in density of the phasor points creates a disadvantage where the transmitted power is no longer constant. In fact, if the average transmitted signal  
10 power is limited, the maximum I and Q values are nearly the same for all the QAM levels, thereby causing the constellation points to be closely spaced as the QAM level increases. Since the distance between phasor points on a QAM constellation generally decreases with additional phasor points, it increases the complexity of distinguishing  
15 neighboring phasor points, and translates into a more expensive and complex receiver.

          Thus, many older or existing DBS (Direct Broadcasting Satellite) systems employ Quaternary (Quadriphase) Phase Shift Keying (QPSK)  
20 modulation systems. For QPSK, a synchronous data stream is modulated onto a carrier frequency before transmission over the satellite channel, where the carrier can have four (phase) states, e.g., 45°, 135°, 225° or 315°. Thus, similar to QAM, QPSK employs quadriphase or quadrature modulation where the phasor points can  
25 be uniquely described using two orthogonal coordinate axes.

          However, in contrast to QAM, QPSK has a "constant envelope", i.e., the pair of coordinate axes can be associated with a pair of quadrature carriers with a constant amplitude, thereby creating a  
30 four level constellation (four phasor points having a phase rotation of

90°). This large separation of phasor points decreases the complexity of performing carrier recovery operation at a receiver, and the constant envelop is extremely desirable for power sensitive satellite transmission systems. Also, the constant power level allows the  
5 satellite amplifiers to operate in saturation.

Nevertheless, the desire to increase the data throughput over a satellite channel has created a strong incentive to consider other transmission schemes instead of QPSK. Due to the existence of  
10 numerous QPSK systems, it is herein recognized as desirable to provide a method and apparatus for processing a signal such as a QAM signal using a backward compatible hierarchical coding scheme to increase data transmission using finer constellations, while maintaining compatibility with existing systems including DBS  
15 systems.

The present invention employs multiple stages of decoders such that the finer constellations of a high order constellation signal such as a QAM signal are unraveled at different stages. More specifically,  
20 at each stage, a decoder such as a Viterbi decoder operates with respect to a lower order constellation such as a QPSK constellation. By connecting a plurality of Viterbi decoders, QPSK demodulation is extended to process 16, 64 and 256 QAM with 1, 2, and 3 extra Viterbi decoders, respectively, and so on.

*Brief Description of the Drawings*

In the drawing,

FIG. 1 depicts a block diagram of a communication system  
5 implementing the present invention;

FIG. 2 depicts a 16-QAM constellation diagram with respect to a  
system implementating the present invention;

FIG 3 depicts a 64-QAM constellation diagram with respect to a  
system implementing the present invention;

10 FIG. 4 is a block diagram depicting the mapping of a data stream  
into I and Q components; and

FIG. 5 depicts a constellation diagram to facilitate a better  
understanding of a system according to the principles of the present  
invention.

15

In the drawings, identical reference numerals have been used to  
designate identical elements that are common to the figures.

A preferred embodiment of the invention is described in the  
20 context of a backwards compatible hierarchical (QAM) signal coding  
system especially attractive for use in, but not limited to, satellite  
transmission systems such as DBS. The system permits additional  
features or services to be added to a datastream without creating  
compatibility problems for existing direct broadcast satellite and  
25 other communications systems.

For example, an "X-QAM" constellation is represented as N  
hierarchical levels of another constellation such as QPSK to produce  
backward compatibility with existing DBS systems, resulting in a  
30 transparent system such that existing QPSK receivers can operate as

5

originally intended. The constellation diagram preferably is hierarchically symmetrical so that the constellation (eg., QPSK) for each decoder (eg., Viterbi) is the same. Asymmetric constellations are possible, however.

5

More specifically, a 64-QAM signal comprises three nested QPSK constellations. The primary QPSK constellation (a quadrant of the 64-QAM signal) can be received by existing DBS receivers. If subtracted from the 64-QAM signal, a 16-QAM signal remains, at a power level 6 db lower than the received signal. The quadrants of the 16-QAM remainder are considered another DBS type signal. The decoding process continues until all levels of the QAM signal are decoded, as will be explained in greater detail. A 16-QAM system according to the invention increases the capacity of a DBS system by a factor of 2, a 64-QAM system by a factor of 3, and a 256-QAM system by a factor of 4.

FIG. 1 illustrates a block diagram of a communication system 100 that employs the present invention. As in many conventional communication systems, communication system 100 will input data, perform some form of processing and frequency translation within a transmitter 110. The data is transmitted over a transmission channel 120 to a receiver 130 which performs the converse operations to recover the input data.

25

However, unlike a conventional communication system, the present invention transmits a QAM signal using a backward compatible hierarchical coding method to increase data transmission using finer, higher order constellations, while maintaining compatibility with existing DBS systems, e.g., as illustrated in dashed

30

box 140 in receiver 130. A detailed description is now presented below where FIGs. 1-3 should be referred to collectively to appreciate the present invention.

5           It is well known that communication systems must address the problem of signal degradation during transmission. However, digital systems such as satellite systems must address additional problems such as transmission path delay, interference, nonlinearity and multideestinational characteristics. Fortunately, these problems can be  
10       minimized by implementing various coding methods. As such, proper selection of a coding strategy is crucial to the performance of communications systems such as a satellite system.

          FIG. 1 illustrates a communication system that employs a  
15       concatenated code. A concatenated code consists of two separate codes which are combined to form a larger code. The two codes are concatenated as illustrated in FIG. 1, where transmitter 110 comprises an outer encoder 112 and an inner encoder 114. Typically, the input signal is arranged as a series of k-bit symbols and inner encoder 114  
20       encodes the k bits of each symbol, while outer encoder 112 encodes a block of k-bit symbols.

          Concatenated coding not only enhances error correction of the transmitted signal, but also supports multiple services and multiple  
25       rate transmission. Due to its advantageous properties, many existing DBS systems are designed to decode concatenated codes.

          More specifically, outer encoder 112 may implement a coding method which is referred to as "block coding". In brief, a block code  
30       is generated where each block of k information bits is mapped into a



code word of length  $n$  selected from a set of  $M=2^k$  code words (where  $k < n$ ). Examples of block encoding methods include but are not limited to Hamming codes, Hadamard codes, Cyclic codes, and the Reed-Solomon (RS) codes.

5

In turn, inner encoder 114 may implement a coding method which is referred to as "convolutional coding". In brief, a convolutional code is generated by passing a data sequence to be transmitted through a linear finite-state shift register. The shift  
10 register (not shown) generally consists of  $K$  ( $k$ -bit) stages and  $n$  linear function generators. Although the present invention is described below with an outer "block" encoder and an inner "convolutional" encoder, those skilled in the art will realize that the present invention is not so limited and that other encoder combinations exist (e.g., an  
15 outer non-binary block encoder combined with an inner binary block encoder).

Returning to FIG. 1, the encoded signal from the inner encoder is passed to a mapper 116 where the encoded signal bits are mapped  
20 onto streams modulating the quadrature I and Q carriers. The mapper can be implemented as a look-up table where sets of bits from the encoded signal are translated into I and Q components (levels) representing constellation points or symbols. In the preferred embodiment, the constellation points are in accordance with  
25 a 16-QAM square constellation, where each phasor is represented by a four-bit symbol, having in-phase bits  $i_1, i_2$ , and quadrature bits  $q_1$  and  $q_2$ . However, it should be understood that the present invention can be adapted to 64-QAM and 256 QAM constellations (and so on) as discussed below.

Finally, the I and Q components are modulated by a QAM modulator (MOD) 118, where the I channel is mixed with an intermediate frequency (IF) signal that is in phase with respect to the carrier. The Q channel is mixed with an IF that is 90 degrees out of phase. This process permits both signals to be transmitted over a single transmission channel 120 within the same bandwidth using the quadrature carriers.

At receiver 130, the I and Q components are recovered and demodulated. Since it is important that the present coding method is backward compatible with existing DBS systems, FIG. 1 illustrates a conventional (DBS) receiver 140 in dashed lines. Although the received encoded bitstream may contain additional information, older receivers will continue to operate normally, i.e., functioning as a QPSK system. The additional information is not recovered, but the encoded bitstream is still compatible with the older receivers. This provides the important advantage of embedding additional information (e.g., on screen display (OSD) messages, increased resolution of the encoded images, or more channels), which can be unraveled by more advanced, multiple decoders as will be discussed without degrading the performance of existing receivers. A consumer has the option of upgrading to a new receiver to gain access to the added information or features, or keeping the older receiver and forego the added features and expense.

Returning to FIG. 1, the modulated signal is demodulated by demodulator 142 to produce the I and Q components. A demapper 144 attempts to translate the I and Q components (levels) into the encoded signal.

As discussed above, a satellite system may experience severe signal degradation as the signal passes through transmission channel 120. As such, it is the task of the receiver decoders to properly  
5 decipher the encoded information from a possibly corrupted bitstream. The encoded bitstream from demapper 144 is received by a first inner decoder 146, which is a "soft decision" Viterbi decoder. The Viterbi decoder implements a probabilistic decoding method where the bitstream is decoded by also considering the transmission  
10 channel statistics, rather than by a fixed set of code-dependent algebraic operation. Namely, the decoder attempts to determine the most likely values that were transmitted.

More specifically, a convolutional code can be described by a  
15 tree diagram, a state diagram or, most often, a trellis diagram. These diagrams illustrate the output sequence of a convolutional code in response to a particular input bit, thereby generating a predictable output sequence structure. Convolutional code exhibits an important behavior, where the structure repeats itself after a particular stage  
20 (otherwise known as path merges). The specific characteristics of a structure depends upon a particular convolutional code. In brief, the Viterbi decoder exploits the path merges of the trellis structure of the convolutional code and exhaustively examines all distinct paths at every trellis level. The Viterbi decoder then computes the most likely  
25 path from a plurality of "surviving" paths, where the selected path is generally the minimum distance path. In this fashion, the Viterbi decoder is able to error correct corrupted bitstream at the expense of increasing the computational overhead.

10

Although the first inner decoder is described as a Viterbi decoder, other decoders may be used. Other decoding methods (whether soft decision or hard decision) such as "sequential decoding" or various modified Viterbi decoding methods can be implemented in  
5 the first inner decoder.

In the preferred embodiment, first Viterbi decoder 146 operates with respect to a QPSK constellation, as in older existing receivers. Namely, the first Viterbi decoder is only able to isolate the  
10 encoded signal to one quadrant. More specifically, FIG. 2 illustrates a 16 QAM constellation diagram having 16 constellations points or symbols occupying four quadrants. The two least significant bits (LSB) 210 of each symbol isolate the encoded signal to a quadrant. Namely, the LSB of all points in a quadrant are identical. As such,  
15 first Viterbi decoder 146 is only able to decode the two LSB 210 of the received symbol from the encoded signal.

The first Viterbi decoder 146 within existing receivers is generally not designed to produce the symbol itself, but instead,  
20 produces a convolutionally decoded data bit(s) represented by the symbol. As such, two LSB 210 of the received symbol is regenerated after the decoded data bit is reencoded by reencoder 160 as discussed below.

25 To illustrate, if the encoded signal carries the symbol "1101", then the first Viterbi decoder is only able to isolate the encoded signal to quadrant 205, thereby producing the bits "01". However, the two most significant bits (MSB) "11" 220 of the symbol are not decoded by the first Viterbi decoder, since its capability is limited to a QPSK  
30 constellation. The additional information is simply ignored by the

11

first Viterbi decoder, where, in turn, it is decoded by other decoders in the receiver as discussed below.

Returning to FIG. 1, the decoded signal from first Viterbi decoder 146 is passed to outer decoder 148. Namely, the bits corresponding to block encoded words are passed to outer decoder 148. It is the task of the outer decoder to detect and account for the error pattern in the received code word and generate the proper code word, i.e., the original input or source signal encoded by the transmitter. Namely, the outer decoder unravels the outer layer of encoding to produce the original input signal.

Generally, the outer decoder compares the received code word with "M" possible transmitted code words (which depends upon the block code implemented at the transmitter) and chooses the code word that is closest in Hamming distance to the received code word. The Hamming distance is a measure of the number of bit positions in which two code words differ.

In the preferred embodiment, the outer decoder is a Reed-Solomon (RS) decoder. The Reed-Solomon code is a linear non-binary block code which is a subclass of the Bose-Chaudhuri-Hocquenghem (BCH) block codes. The RS decoder is well known for its capability to address burst errors, especially when used in combination with interleaving strategies. Interleaving is a process where errors are distributed over several encoded sequences to minimize the effect of a long burst error, which may corrupt the encoded sequence beyond the error correction capability of the code. Thus, a transmitter may incorporate an interleaver (not shown) before modulating the

1 2

encoded signal, which, in turn, requires the receiver to incorporate a deinterleaver (not shown) after performing demodulation.

Although the disclosed system employs an outer RS decoder,  
5 various other block decoding methods can also be implemented within the outer decoder. Thus, if a receiver comprises only portion 140 as illustrated in FIG. 1, such receiver would still be able to unravel and decode the encoded bitstream transparently with respect to a QPSK constellation.

10

Returning to FIG. 1, if finer constellations are to be unraveled, then a second Viterbi decoder 170 is employed to decode the next level or resolution in the hierarchical code. More specifically, second decoder 170 receives inputs from a reencoder 160 and delay 150.

15 The reencoder receives the decoded bits from the first Viterbi decoder and reencodes these bits to provide the quadrant information necessary for the second Viterbi decoder. Specifically, the first Viterbi decoder isolates to a quadrant with respect to a QPSK constellation and then using this constellation point, removes the  
20 convolutional coding and produces a decoded data bit. The decoded data bit from the first Viterbi decoder 146 is the actual signal which is generally subjected to block encoding. This decoded data bit is not useful to the second Viterbi decoder in this form and is therefore reencoded to define the quadrant in which the second Viterbi decoder  
25 is to operate.

Since the present invention is described with reference to an existing DBS system, it is assumed that Viterbi decoder 146 is only able to generate a decoded data bit. However, those skilled in the art  
30 will realized that a Viterbi decoder can be implemented such that the

13

quadrant information can be extracted directly from first Viterbi decoder 146 via path 155 without the use of reencoder 160.

Delay section 150 receives inputs from demapper 144 and  
5 delays the encoded signal. Since first Viterbi decoder 146 and reencoder 160 incur a certain amount of latency (delay) in performing their operations, this delay is necessary to synchronize the data from the reencoder with the appropriate data from the demapper. Once synchronization is achieved, second Viterbi decoder  
10 170 then further isolates the signal to a quadrant within the quadrant specified by first Viterbi decoder 146.

To illustrate, returning to FIG. 2, the first Viterbi decoder may isolate the signal to the quadrant "01" (the two LSB) 210, but it is  
15 unable (or is not designed) to refine the isolation to the two MSB "11" 220 in this quadrant. As such, reencoder 160 informs second Viterbi decoder 170 to operate in this upper left most quadrant where the second Viterbi decoder isolates the signal to "11" 220. The first Viterbi decoder is effectively defining which portion (subset) of the  
20 16 QAM constellation for second Viterbi decoder to operate. In this manner, the second Viterbi decoder 170 unravels the two MSB and produces decoded data bits to outer decoder 148 where block decoding is performed to recover the original input signal encoded by the transmitter. It should be noted that block decoding performed by  
25 RS decoder 148 is implemented in an interleaved fashion for backward compatibility reasons. However, there are many possible architectures for the block decoding. Each additional Viterbi inner code could be conceivably linked to an outer interleaving/Reed-Solomon coding scheme. It is also possible to design a single

14

interleaving/block outer coding scheme for all but the innermost convolutional code (for compatibility reasons).

Extending this architecture, it is possible to decode ever finer  
5 constellations with additional Viterbi decoding stages, e.g., delay 150, reencoder 160 (optional) and second Viterbi decoder 170 constitute a single decoding stage (Viterbi decoding stage). For example, a third Viterbi decoding stage (not shown) can be added to the receiver 130 to decode a 64 QAM signal.

10

To illustrate, FIG. 3 depicts a 64 QAM constellation. The first Viterbi decoder 146 is able to isolate the signal to the two LSB "01" 310 of the received symbol which define 16 possible constellation points in the upper left most corner of the constellation diagram. In  
15 turn, second Viterbi decoder 170 is able to further isolate the signal to the two average significant bits (ASB) "11" 320, which define four (4) possible constellation points in the lower left most corner within the region of the constellation diagram defined by the first Viterbi decoder. Finally, the third Viterbi decoder (not shown) is able to  
20 ultimately isolate the signal to the two MSB "00" 330 which define a particular constellation point from the four (4) remaining possible constellation points. In this fashion, a symbol "001101" is unraveled using three different stages of Viterbi decoders.

25 Thus, it is possible to represent an "x-QAM" constellation as "n" hierarchical levels of (QPSK) constellation. For example, a 16-QAM constellation can be represented as two (2) hierarchical levels of (QPSK) constellation and a 64-QAM constellation can be represented as three (3) hierarchical levels of (QPSK) constellation and so on.



It should also be noted that the constellation diagram is hierarchically symmetrical. Namely, the QPSK constellation for each Viterbi decoder is the same. For example, the constellation point "00" is always the upper right most constellation point, such that the constellation point "000000" is the upper right most constellation point for the 64 QAM constellation diagram, and so on for a 256 QAM constellation. This symmetry simplifies the construction of the receiver where similar Viterbi decoders of low complexity can be used in any decoding stage. However, it should be understood that the present invention is not so limited and that other constellation orders can be used.

FIG. 4 illustrates a block diagram depicting the mapping of a data stream 405 into I and Q components on paths 430 and 440 respectively via a mapper 420. To exploit the receiver architecture of FIG. 1, the encoded bitstream is mapped hierarchically into I and Q components such that receivers of different complexity will be able to decode the encoded bitstream without encountering compatibility problems.

More specifically, encoded bitstream 405 comprises a plurality of bits which are grouped into a plurality of symbols 410. Each successive pair of bits starting from the LSB to the MSB within each symbol is unraveled by successive Viterbi decoding stages as discussed above. Namely, bits 412, 414, 416 and 418 are unraveled by the first, second, third and fourth Viterbi decoding stages respectively. Each pair of bits may represent a different channel, a different service or a different resolution. This advantageous hierarchical coding method permits additional features or services to

16

be added into the bitstream without creating compatibility problems for existing DBS systems.

In Figure 4, each symbol is an eight bit symbol associated with a 256-QAM signal constellation. Each symbol is constituted by four two-bit pairs 412, 414, 416 and 418, where each pair of bits of each symbol represents information for a different service or feature. The illustrated 8-bit symbol 10 00 01 11 represents a 256-QAM constellation as illustrated, a nested 64-QAM constellation (bits 00 01 11), a nested 16-QAM constellation (bits 01 11) and a nested QPSK constellation symbol (bits 11). The symbol bits are designated most significant (418) to least significant (412) from left to right. In this hierarchical ordering of QPSK constellations, each successive pair of symbol bits from the LSB to the MSB is successively decoded, or unraveled, at a receiver by successive decoders as explained previously. Thus high order QAM constellations are decoded as QPSK.

One possible arrangement of the hierarchical constellations is shown in more detail in Figure 5. Figure 5 shows the hierarchical progression of constellations from a two bit/symbol QPSK (highlighted in the uppermost right corner of Figure 5), to a four bit/symbol 16-QAM constellation which represents the first level finer unraveling of the constellation, then to a six bit/symbol 64-QAM constellation, finally to a 256-QAM constellation. Only a portion of the lower left quadrant of the 256-QAM constellation is shown.

The symbol points in the illustrated lower left quadrant of the 256-QAM constellation are of the form xxxxxx11 such that all of the 64 constellation points in this quadrant have two common LSBs of "11." Similarly, all of the 64 points in each of the other quadrants of

17

the 256-QAM constellation are of the form xxxxxx00 for the upper right quadrant, xxxxxx10 for the upper left quadrant, and xxxxxx01 for the lower right quadrant. It is noted that the bit combinations 00, 10, 11 and 01 are respectively associated with the signal points in the  
5 four quadrants of a QPSK constellation.

At the next level, 16 constellation points (of which there are four clusters shown in Figure 5) have the third and fourth signal bits in common in respective quadrants (in addition to the LSBs noted  
10 above) corresponding to a 16-QAM constellation. At the third level, 4 constellation points (of which there are 16 clusters) have another two signal bits in common in respective quadrants. Finally, at the fourth level, each point represents a unique 256-QAM constellation point. The 256-QAM signal point discussed in connection with Figure 4,  
15 "10000111," is highlighted with a dotted outline in the lower right quadrant of Figure 5.

It should be noted that although alignment can be performed on symbol boundaries, it can also be implemented on packet boundaries  
20 as well. Additionally, it is possible to map the bits from MSB to LSB order.

In the preferred embodiment, if additional services are added, additional power is generally transmitted at the rate of an additional  
25 3 dB for each doubling of the signal constellation. To achieve the same error performance, the SNR (signal to noise ratio) needs to be increased roughly by 3 db for every doubling of the signaling alphabet. An additional backoff is necessary especially in satellite systems so that the traveling wave tube (TWT) amplifiers are not  
30 operated in saturation as is often the case with QPSK systems. This is

18

necessitated by the fact that QAM systems are much more susceptible to non-linear distortion effects caused by saturating amplifiers.

Alternatively, it is possible to minimize the increase in transmitted power by making some coding tradeoffs.

5

Furthermore, the present hierarchical coding/decoding method is not limited to satellite systems and can be extended to provide varying grades of service over other media as well.

19  
CLAIMS:

1. A receiver for receiving a Quadrature Amplitude  
Modulation (QAM) modulated bitstream containing phasor points  
5 represented in a QAM constellation, said receiver (130) comprising:  
a first decoder (146) for decoding the QAM modulated bitstream  
with respect to a Quaternary Phase Shift Keying (QPSK) constellation  
to produce a decoded bitstream; and  
a second decoder (170), coupled to said first decoder, for  
10 decoding the QAM modulated bitstream with respect to a QPSK  
constellation within a subset region of the QAM constellation defined  
by said first decoder.

2. The receiver of claim 1, further comprising:  
15 a delay, coupled to said second decoder, for applying a delay;  
and  
a reencoder, coupled to said first decoder, for generating  
information relating to said subset region defined by said first  
decoder.

20 3. The receiver of claim 2, wherein  
said delay, said reencoder and said second decoder forms a  
decoding stage, where additional decoding stages are added to decode  
finer constellations of the QAM modulated bitstream.

25 4. The receiver of claim 1, further comprising:  
an outer third decoder, coupled said first decoder, for decoding  
said decoded bitstream from said first decoder.

20

5. A method of decoding a Quadrature Amplitude Modulation (QAM) signal having a plurality of QAM phasor points represented by a QAM constellation diagram having "n" hierarchical levels of Quaternary Phase Shift Keying (QPSK) constellation, said method  
5 comprising the steps of:

(a) using a first decoder to decode a first hierarchical level of the QAM signal with respect to a QPSK constellation to produce a decoded signal; and

10 (b) using a second decoder to decode a second hierarchical level of the QAM signal with respect to a QPSK constellation, within a subset region of the QAM constellation defined by said first decoder.

6. The method of claim 5, including  
using additional decoders to decode additional hierarchical  
15 levels of the QAM signal.

7. The invention as defined in claim 2 or claim 5, wherein said first and second decoders are convolutional decoders.

20 8. The invention as defined in claim 7, wherein said convolutional decoders are Viterbi decoders.

9. The method of claim 5, further comprising the steps of:  
a1) applying a delay to the QAM signal; and  
25 a2) encoding said decoded signal from said first decoder to generate information relating to said subset region defined by said first decoder.

10. The method of claim 5, further comprising the step of:  
c) using a third decoder to decode said decoded signal from  
said first decoder.

5

11. The invention as defined in claim 4 or claim 10, wherein  
said third decoder is a block decoder.

10

12. The invention as defined in claim 11, wherein  
said block decoder is a Reed-Solomon decoder.

15

13. In a satellite signal receiver, a method of decoding a  
Quadrature Amplitude Modulation (QAM) signal having a plurality of  
QAM symbol points represented by a QAM constellation diagram  
having N hierarchical levels of a Quaternary Phase Shift Keyed (QPSK)  
constellation, said method comprising the steps of:

20

demodulating an input QAM signal received from a satellite  
transmission channel to produce a demodulated QAM signal; and  
using a plurality of decoders for successively decoding  
respective hierarchical levels of said demodulated QAM signal.

25

14. A method according to claim 13, wherein  
said step of successively decoding respective hierarchical levels  
is with respect to a QPSK constellation.

15. A method according to claim 13, wherein  
said decoders are Viterbi decoders.

100

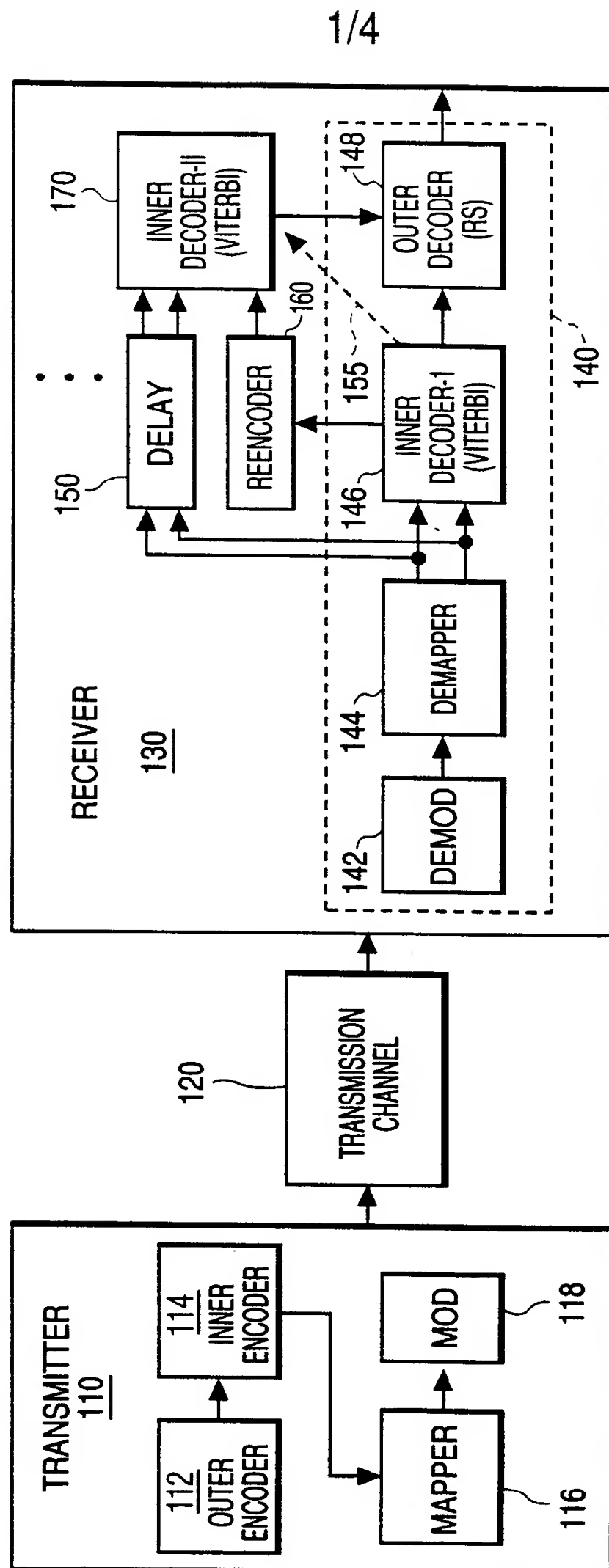


FIG. 1



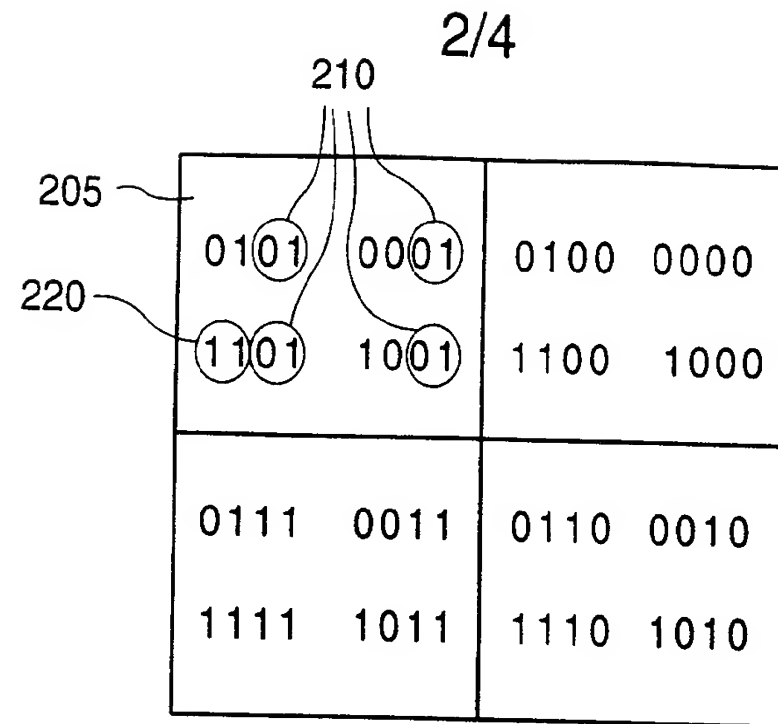


FIG. 2

010101 000101	010001 000001	010100 000100	010000 000000
110101 100101	110001 100001	110100 100100	110000 100000
011101 001101	011001 001001	011100 001100	011000 001000
111101 101101	111001 101001	111100 101100	111000 101000
010111 000111	010011 000011	010110 000110	010010 000010
110111 100111	110011 100011	110110 100110	110010 100010
011111 001111	011011 001011	011110 001110	011010 001010
111111 101111	111011 101011	111110 101110	111010 101010

FIG. 3

3/4

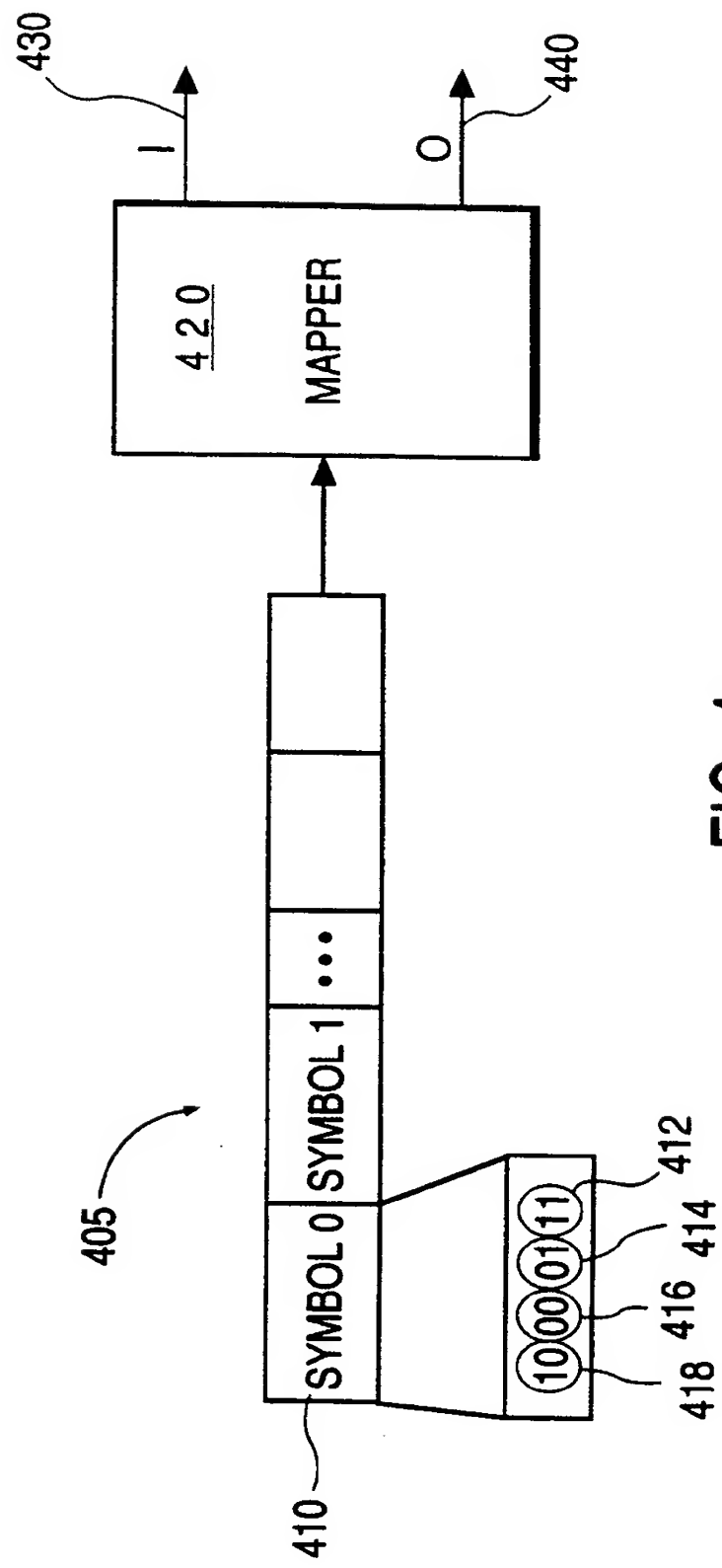
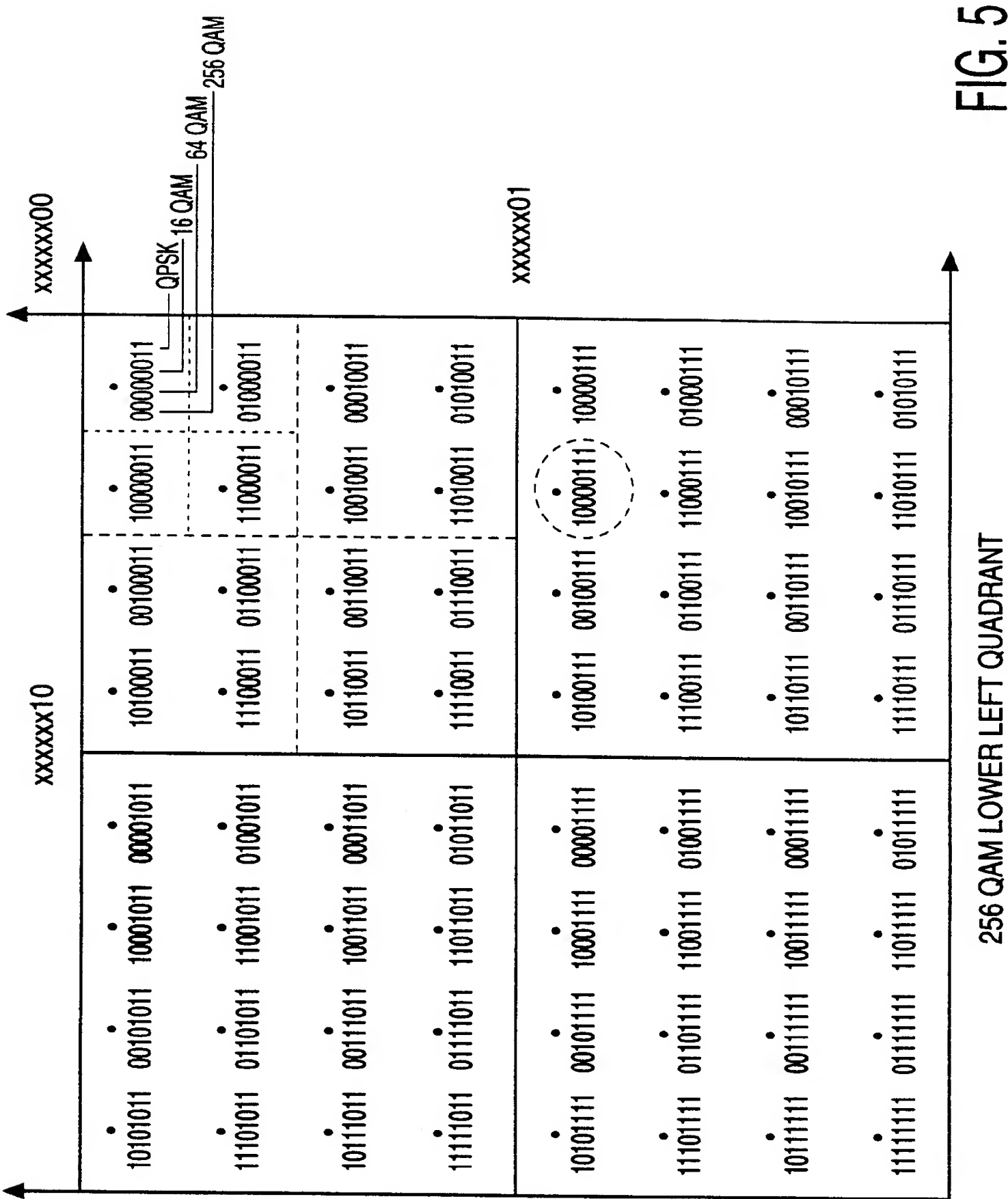


FIG. 4



## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 98/12641

## A. CLASSIFICATION OF SUBJECT MATTER

H 04 L 27/38, H 04 B 7/185

According to International Patent Classification (IPC) or to both national classification and IPC 6

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H 04 L, H 04 B, H 03 M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A -	GB 2280571 A (BRITISH BROADCASTING CORP.) 01 February 1995 (01.02.95), abstract, page 2, line 32 - page 5, line 40, fig. 1-5. --	1, 5, 13
A	EP 0589709 A2 (MATSUSHITA) 30 March 1994 (30.03.94), abstract, page 7, line 57 - page 11, line 31, fig. 1-20. --	1, 5, 13
A	Patent Abstracts of Japan, Vol. 18, No. 608 (E-1633), 18 November 1994; & JP, A, 06-232939 A (MATSUSHITA), 19 August 1994. ----	1, 2, 5, 9, 13



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

12 August 1998

Date of mailing of the international search report

22.09.98

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+ 31-70) 340-2040, Tlx. 31 651 epo nl,  
Fax (+ 31-70) 340-3016

Authorized officer

HAJOS e.h.

zum internationalen Recherchen-  
bericht über die internationale  
Patentanmeldung Nr.

to the International Search  
Report to the International Patent  
Application No.

au rapport de recherche inter-  
national relatif à la demande de brevet  
international n°

La présente annexe indique les  
membres de la famille de brevets  
relatifs aux documents de brevets cités  
dans le rapport de recherche inter-  
national visée ci-dessus. Les renseigne-  
ments fournis sont donnés à titre indica-  
tif et n'engagent pas la responsabilité  
de l'Office.

[illegible]

EP	A3	555031	15-11-95
JF	A2	6180888	28-06-94
JF	A2	6231510	19-08-94
JF	A2	6036387	10-02-94
JF	A2	53007788	19-11-93
JF	A2	5250756	28-09-93
JF	A2	6231509	19-08-94
ON	A	1119895	03-04-96
ON	A	1138915	25-12-96
EP	A1	741382	06-11-96
EP	A4	741382	02-07-97
CS	A	5761301	02-06-98
WO	A1	9616401	30-05-96
UP	A2	8212681	20-08-96
ON	A	1166223	26-11-97
ON	A	1173942	18-02-98
EP	A1	802527	22-10-97
EP	A1	807929	19-11-97
EP	A4	802527	10-12-97
EP	A4	807929	10-12-97
WO	A1	9714144	17-04-97
WO	A1	9714146	17-04-97

---

JP	A2	6232939	19-08-94	keine - none - rien
----	----	---------	----------	---------------------

---